OFFICE OF TRANSPORTATION TECHNOLOGIES

The Office of Transportation Technologies seeks to develop, in cooperation with industry, technologies that are more energy efficient, that will enable the transportation sector to shift to alternative fuels and electricity, and that will minimize the environmental impacts of transportation energy use. Materials research and development within the Office of Transportation Technologies is conducted by the Office of Transportation Materials, the Office of Propulsion Systems, and the Office of Alternative Fuels, each having responsibility for specific technologies and program areas.

OFFICE OF TRANSPORTATION MATERIALS

The overall goal of the Materials Technology Program is to develop, in concert with the United States-based industry, an industrial technology base in cost-effective, advanced transportation-related materials and associated processing of these materials. The timely availability of these materials and processing techniques will enable the development of more energy-efficient transportation technologies capable of utilizing alternative fuels and electricity. Research and development activities focus on: (a) propulsion system materials (specifically cost-effective ceramics which are critical to the development of more efficient advanced heat engines for transportation propulsion); (b) vehicle system materials (specifically lightweight materials that could aggressively reduce the weight and improve the fuel economy of vehicles without compromise to passenger comfort and safety); and (c) operation of the High Temperature Materials Laboratory.

The Propulsion System Materials Program focuses on the development of reliable, cost-effective ceramics to facilitate their commercial introduction in propulsion systems. Program efforts concentrate on reducing the cost of ceramic components and improving their performance. A majority of the research is conducted by industry. The Ceramic Technology Program is managed by the Oak Ridge National Laboratory (ORNL). The DOE Contact is Robert Schulz, (202) 586-8051.

The Vehicle System Materials Program focuses on the development of cost-effective processing and manufacturing of advanced lightweight material components that will, in the near term, continually improve the fuel economy of current production vehicles, and in the long term, allow aggressive weight reductions needed for hybrid and electric vehicles. Lightweight materials will be increasingly important in achieving the energy, economic, and environmental goals for the transportation sector. The DOE Contact is Sidney Diamond, (202) 586-8032.

The High Temperature Materials Laboratory (HTML) at the Oak Ridge National Laboratory is a state-of-the-art research and user facility which supports advanced materials research conducted by the Department of Energy, as well as by industry, universities, and other research and development laboratories. The HTML currently includes six user centers (equipped primarily for characterizing materials), namely: materials analysis, high temperature mechanical properties, high temperature x-ray diffraction, physical properties, ceramic specimen preparation, and residual stress measurements. A seventh center includes instrumentation for conducting sophisticated research on machining of advanced ceramic materials with the goal of working directly with industrial teams to achieve cost-effective manufacturing. The DOE Contact is Debbie Haught, (202) 586-2211.

MATERIALS PREPARATION, SYNTHESIS, DEPOSITION, GROWTH OR FORMING

42. **POWDER CHARACTERIZATION (WBS NO. 1118)**
$110,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: D. R. Johnson, (423) 576-6832
NIST Contact: S. Malghan, (301) 975-2000

This effort is directed toward developing a fundamental understanding of surface chemical changes which take place when silicon nitride powder is attrition milled in an aqueous environment. This project also will demonstrate the use of and establish operating conditions for high energy attrition milling of silicon nitride powder. These tasks will be accomplished by developing measurement techniques and data on the effect of milling variables on the resulting powder. It is expected that information gained from this study will serve in the identification and development of appropriate characterization procedures, process control techniques, and in certification of new Standard Reference Materials.

Keywords: Powder Characterization, Powder Processing, Reference Material, Silicon Nitride

43. **MICROWAVE SINTERING (WBS NO. 1124)**
$400,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: D. R. Johnson, (423) 576-6832
ORNL Contact: T. N. Tiegs, (423) 574-5173

The objective of this effort is to identify those aspects of microwave processing of silicon nitride that might

(1) accelerate densification, (2) permit sintering to high density using much lower levels of sintering aids, (3) lower the sintering temperature, (4) produce unique microstructures, or (5) contribute to cost-effectiveness of silicon nitride materials.

Early work included investigations of the microstructure development of dense silicon nitride materials annealed in the microwave furnace and the sintering of silicon nitride powder compacts in the 2.45- or 28-GHz units. While improvements were observed in the properties of the materials fabricated, the cost-effectiveness of the microwave processing was marginal. Another approach dealt with the fabrication of sintered reaction-bonded silicon nitride (SRBSN) and was done entirely in the 2.45-GHz microwave furnace. SRBSN is a cost-effective method to fabricate silicon nitride ceramics. Raw materials costs are less than about 1/4 those for high-purity silicon nitride materials, which improves the cost-competitiveness of these materials with metal parts. Conventional SRBSN requires long nitridation times and two-step firing. By using microwave heating, nitridation times are reduced and all firing is performed in a one-step continuous process, simplifying the operation. Current activities involve the scale-up of the microwave process to large quantities of parts.

Keywords: Microwave Sintering, Silicon Nitride, SRBSN

44. **COST-EFFECTIVE SILICON NITRIDE POWDER (WBS NO. 1125)**
$0
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: S. G. Winslow, (423) 574-0965
Dow Contact: G. A. Eisman, (517) 638-7864

The objective of this program is to further advance the carbothermal nitridation process for producing silicon nitride powder developed under Phase I by focusing on issues relating to the overall cost of manufacturing the powder. Phase II tasks are designed to (1) determine feasibility of using low-cost raw materials and their impact on the final product quality; (2) reduce processing costs; and (3) characterize, process, fabricate modulus of rupture (MOR) test specimens, and evaluate the mechanical properties of the lower cost powder.

Keywords: Cost Effective Ceramics, Silicon Nitride, Powder Synthesis, Powder Characterization

45. **COST-EFFECTIVE SINTERING OF SILICON NITRIDE CERAMICS (WBS NO. 1127)**
$121,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: T. N. Tiegs, (423) 574-5173
Southern Illinois University (SIU) Contact:
D. E. Wittmer, (618) 453-7006/7924

The objective of this effort is to investigate the potential of cost-effective sintering of Si_3N_4 through the development of continuous sintering techniques and the use of lower cost Si_3N_4 powders and sintering aids. Specifically, the tasks for Phase III are to: (1) continue the evaluation of continuous sintering parameters on properties of selected Si_3N_4 compositions, (2) continue the evaluation of low-cost Si_3N_4 powders, (3) design and construct a prototype belt furnace capable of sintering a large number of parts. The prototype belt furnace has been constructed by Centorr/Vacuum Industries, Inc., and installed and tested at SIU.

Keywords: Cost Effective Ceramics, Silicon Nitride, Sintering

46. **ADVANCED PROCESSING (WBS NO. 1141)**
$0
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: R. L. Beatty, (423) 574-4536
Norton Contact: D. M. Tracey, (508) 393-5811

The purpose of this task was to develop and demonstrate significant improvements in processing methods, process controls, and nondestructive evaluation (NDE) which can be commercially implemented to produce high-reliability silicon nitride components for advanced heat engine applications at temperatures to 1370°C.

A silicon nitride - 4 wt % yttria composition was used and densification was performed by glass encapsulation hot isostatic pressing. Process demonstration provided data and experience which suggest that the material developed in this program, NCX-5102, truly ranks as a world-class silicon nitride material. The test program established a mean tensile strength of 997 MPa with a fracture toughness approaching 7 $MPa \cdot m^{1/2}$ for the demonstration set of 320 tensile rods.

Keywords: Nondestructive Evaluation, Silicon Nitride, Processing, Processing Controls

47. **IMPROVED PROCESSING (WBS NO. 1142)**
$650,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contacts: D. R. Johnson, (423) 576-6832 and S. D. Nunn, (423) 576-1668

The purpose of this work is to develop gelcasting as an advanced, near-net-shape ceramic forming process. This program will address the technical aspects of the gelcasting process, evaluation of the applicability of gelcasting to a wide range of commercially available ceramic powders, and identification and assessment of manufacturing concerns and issues as they relate to commercialization of gelcasting. The emphasis of the program will be on gelcasting of silicon nitride ceramics and developing industry acceptance of the process. Issues of practicality and environmental safety and health (ES&H) will be addressed in the development of the program. The technical feasibility of in-process and NDE testing methods for improving quality and reliability of gelcast ceramics will also be addressed.

Keywords: Powder Processing, Silicon Nitride, Gelcasting

48. **PROCESSING OF SILICON BASED CERAMICS (WBS NO. 1225)**
$267,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: D. R. Johnson, (423) 576-6832
University of Michigan Contact: T. Y. Tien, (313) 764-9449

The properties of silicon nitride can be optimized by microstructural design, specifically by developing fiber-like β-Si_3N_4 grains and control of the grain-boundary phase. The purpose of this investigation is to optimize the properties of silicon nitride ceramics by microstructure design.

Keywords: Composites, Physical/Mechanical Properties, Silicon Nitride, Toughened Ceramics

49. **IN SITU TOUGHENED SILICON NITRIDE (WBS NO. 1226)**
$353,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: T. N. Tiegs, (423) 574-5173
AlliedSignal Ceramic Components Contact: H. C. Yeh, (213) 618-7449

The purpose of this effort is to develop compositions and processes to obtain high fracture toughness and strength for silicon nitride (Si_3N_4)-based ceramic materials through microstructure control. Under Phase I, an in situ reinforced silicon nitride material (AS800) with elongated grain microstructure was developed. Phase II expanded the AS800 material property database and built on Phase I results to further improve material properties and processing. The objectives of Phase III are to further expand the material properties database, improve high-temperature behavior, and develop cost-effective, advanced fabrication techniques for this material.

Keywords: Cost Effective Ceramics, Physical/Mechanical Properties, Silicon Nitride, Toughened Ceramics

50. **IN SITU TOUGHENED SILICON NITRIDE (WBS NO. 1231)**
$350,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contacts: D. R. Johnson, (423) 576-6832 and T. N. Tiegs, (423) 574-5173

Significant improvement in the reliability of structural ceramics for advanced engine applications could be attained if the critical fracture toughness (K_{Ic}) were increased without strength degradation. Early results from ORNL research showed that significant increases in fracture toughness could be achieved by manipulating the microstructure to promote toughening mechanisms such as crack bridging. Excellent properties were obtained in this manner for the alumina and mullite matrix systems reinforced with SiC whiskers. In silicon nitride, acicular or elongated grains can be generated by in situ growth and these can provide significant toughening on the same order as the whisker-toughened materials. Microstructural development to promote this type of growth in silicon nitride is the current emphasis of this project.

Keywords: Composites, Alumina, Silicon Carbide, SiAlON, Toughened Ceramics

51. **LOW THERMAL EXPANSION CERAMICS (WBS NO. 1243)**
$100,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contacts: D. R. Johnson, (423) 576-6832 and D. P. Stinton, (423) 574-4556

The objective of this effort is to coordinate efforts regarding the application of low-expansion ceramics in advanced heat engines. Contracts have been placed with Golden Technologies, Inc., and LoTEC, Inc., to develop cost-effective processes for the fabrication of portliners. Golden is investigating Al_2TiO_5 and $Ca_{1-x}Mg_xZr_4P_6O_{24}$, while LoTEC is working with $Ba_{1+x}Zr_4P_{6-2x}Si_{2x}O_{24}$ (BaZPS) and $Ca_{1-x}Sr_xZr_4P_6O_{24}$. ORNL is assisting Golden Technologies

and LoTEC with the characterization and evaluation of their compositions.

Keywords: Alumina, Beta-eucryptite, Phosphate, Physical/Mechanical Properties, Structural Ceramics, Ultra-low Expansion

52. **NZP COMPONENTS (WBS NO. 1245)**
$0
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: D. P. Stinton, (423) 574-4556
LoTEC, Inc. Contact: Santosh Limaye, (801) 277-6940

The overall objective of this effort is to develop sodium-zirconium-phosphate (NZP) ceramic-based, "cast-in-place, diesel-engine portliners. Specific objectives are: (1) perform materials requirements analyses, (2) successfully demonstrate metal casting around the ceramic, (3) develop a cost-effective process, and (4) develop a high-temperature database (e.g., stability, thermal cycling, thermal shock) for these materials. LoTEC will continue to develop and scale up production of sodium-zirconium-phosphate (NZP) materials developed at Penn State University.

Keywords: Structural Ceramics, Ultra-low Expansion, Zirconia

53. **LOW COST ALUMINUM TITANATE/NZP CERAMICS (WBS NO. 1246)**
$0
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: D. P. Stinton, (423) 574-4556

The objective of this work was to develop a low-thermal-conducting, high-thermal-shock-resistant, ceramic portliner which can survive casting in grey iron and diesel engine operation. Golden Technologies worked on developing their own aluminum titanate material and, in addition, on scaling up production of a unique NZP material developed at Virginia Polytechnic Institute and State University.

Keywords: Structural Ceramics, Ultra-low Expansion, Zirconia

54. **ADVANCED MANUFACTURING (WBS NO. 1520)**
$397,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: D. R. Johnson, (423) 576-6832
Kyocera Contact: E. Kraft, (206) 750-6147

The objective of this program is to develop the cost-effective manufacturing technology required for ceramic turbine rotors for use in turbochargers for heavy duty diesel truck and bus applications. A team, led by Kyocera and including Schwitzer U.S., Inc. and Caterpillar Inc., will develop and demonstrate production readiness for reliable, cost affordable, turbochargers with ceramic turborotors. Program goals include a nominal order of magnitude reduction in cost over the present cost for small quantities, and process capability for critical component attributes which is adequate for the performance and reliability specifications of the application. Silicon nitride SN 235 is the material of choice for this application.

Keywords: Components, Cost Effective Ceramics, Process Control, Silicon Nitride

55. **ADVANCED CERAMIC MANUFACTURING (WBS NO. 1521)**
$991,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: A. E. Pasto, (423) 574-4956
Norton Contact: Eric Bright, (203) 653-8071

The objectives of this program are to design, develop, and demonstrate advanced manufacturing technology for the production of ceramic exhaust valves for a diesel engine using Norton Advanced Ceramics' NT 451 SiAlON. The component to be developed and tested is the exhaust valve for Detroit Diesel Corporation (DDC)'s Series 149 engine. Specific objectives are to: (1) reduce manufacturing costs by at least an order of magnitude over current levels; (2) develop and demonstrate process capability values of 0.7 or less for all critical component attributes; and (3) to validate ceramic valve performance, durability, and reliability in rig and engine testing.

Keywords: Components, Cost Effective Ceramics, Process Control, SiAlON

56. **ADVANCED CERAMIC MANUFACTURING (WBS NO. 1522)**
$1,543,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: R. L. Beatty, (423) 574-4536

The objective of this program was to develop a cost-competitive, viable manufacturing process for advanced ceramic engine components. To achieve this goal, two components, utilizing two materials, for two engine companies, were selected. Both components share simple, right-circular geometries and similar manufacturing processes. Key challenges in this program were to meet tight tolerances and yet maintain high yields required to meet cost objectives. Three major activities were to occur in parallel: (1) DDC component design/development, (2) Cummins component design/development, and

(3) intelligent processing and statistical process control development/implementation.

Keywords: Components, Cost Effective Ceramics, Process Control

MATERIALS PROPERTIES, BEHAVIOR, CHARACTERIZATION OR TESTING

57. **DEVELOPMENT OF STANDARD TEST METHODS FOR EVALUATING THE WEAR PERFORMANCE OF CERAMICS (WBS NO. 2222)**
$30,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contacts: D. R. Johnson, (423) 576-6832 and P. J. Blau, (423) 574-5377

The goal of this effort is to improve consistency in reporting ceramic wear test data by helping to develop one or more standard test methods for quantitatively determining the wear resistance of structural ceramics in reciprocating sliding, a type of motion which is experienced by several types of engine parts. ORNL is working with the American Society for Testing of Materials (ASTM) to meet this objective.

Keywords: Structural Ceramics, Test Procedures, Wear

58. **ADVANCED STATISTICS CALCULATIONS (WBS NO. 2313)**
$0
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: M. K. Ferber, (423) 576-0818
GE Contact: C. A. Johnson, (518) 387-6421

The design and application of reliable load-bearing structural components from ceramic materials requires a detailed understanding of the statistical nature of fracture in brittle materials. The overall objective was to advance the current understanding of fracture statistics, especially in the areas of optimum testing plans and data analysis techniques, consequences of time-dependent crack growth on the evolution of initial flaw distributions, confidence and tolerance bounds on predictions that use the Weibull distribution and function, strength distributions in multiaxial stress fields, and goodness-of-fit-tests for the Weibull model of strength. The studies were carried out largely by analytical and computer simulation techniques. Actual fracture data were then used as appropriate to confirm and demonstrate the resulting data analysis techniques.

Keywords: Design Codes, Life Prediction, Statistics, Weibull, Fracture, Structural Ceramics, Instrumentation or Technique Development

59. **MICROSTRUCTURAL ANALYSIS (WBS NO. 3111)**
$50,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: D. R. Johnson, (423) 576-6832
NIST Contact: S. M. Wiederhorn, (301) 975-5772

The objective of this work was to identify the mechanisms of failure in structural ceramics subjected to mechanical loads in various test temperatures and environments. This is a companion project to a related task in which advanced ceramics are characterized in tensile creep. Of particular interest is the damage that accumulates in structural ceramics as a consequence of high temperature exposure to environments and stresses normally present in heat engines. Materials studied included sialons, silicon nitride, and sintered silicon carbide.

Keywords: Corrosion, Engines, Erosion, High Temperature Performance, Structural Ceramics, Silicon Carbide, Creep, SiAlON, Silicon Nitride

60. **MICROSTRUCTURAL CHARACTERIZATION OF SILICON CARBIDE AND SILICON NITRIDE CERAMICS FOR ADVANCED HEAT ENGINES (WBS NO. 3114)**
$200,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contacts: D. R. Johnson, (423) 576-6832 and T. A. Nolan, (423) 574-0811

The purpose of this work is to determine the microstructure of both monolithic and composite ceramics and to relate that microstructure to mechanical properties and material performance. Specifically, the materials of interest are silicon carbides and silicon nitrides developed by U.S. manufacturers as part of this program and the Advanced Turbine Technology Applications Program (ATTAP). A major objective is to use electron microscopy and surface chemistry to characterize the chemistry, crystallography, and morphology of phases present with particular emphasis on the structure and chemistry of grain boundaries and other interfaces.

A second major objective is to relate those microstructural observations to available mechanical test data produced by other participants in the ATTAP and Ceramic Technology programs. Ceramic specimens from foreign sources are also characterized to provide comparative information on microstructural properties. A new initiative began in FY 1995. With increased emphasis being placed on supporting the automotive and diesel industry in the U.S., a

program that relates the microstructure of catalysts to catalyst performance has been initiated.

Keywords: Catalyst Performance, Catalysts, Silicon Carbide, Silicon Nitride, Microstructure, Chemical Analysis, Mechanical Properties, Scanning Electron Microscopy

61. **PROJECT DATA BASE (WBS NO. 3117)**
$240,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contacts: D. R. Johnson, (423) 576-6832 and B. L. Keyes, (423) 574-5113

The objective of this effort is to develop a comprehensive computer database containing experimental data on the properties of ceramic materials generated for the Ceramic Technology Project. This computer system should provide a convenient and efficient mechanism for the compilation and distribution of the large amounts of data involved. The database will be available in electronic form to all project participants. In addition, periodic hard copy summaries of the data, including graphical representation and tabulation of raw data, will be issued to provide convenient information sources for project participants.

Keywords: Database, Mechanical Properties, Structural Ceramics

62. **FRACTURE BEHAVIOR OF TOUGHENED CERAMICS (WBS NO. 3213)**
$290,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contacts: D. R. Johnson, (423) 576-6832 and P. F. Becher, (423) 574-5157

Ceramics with reinforcing microstructures and ceramic composites offer important advantages for heat engine applications. In addition to improved fracture toughness, these materials often exhibit substantial improvement in damage, thermal shock, and slow-crack-growth resistance. In this effort, studies are conducted to determine mechanical properties (e.g., creep, delayed failure, strength, and toughness) at elevated temperatures for these toughened ceramics. Particular emphasis is placed on understanding how microstructure and composition influence the mechanical performance at elevated temperatures and the stability of these properties for extended periods.

Keywords: Toughened Ceramics, Mechanical Properties, Silicon Carbide, Silicon Nitride, Alumina

63. **CYCLIC FATIGUE OF TOUGHENED CERAMICS (WBS NO. 3214)**
$220,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contacts: D. R. Johnson, (423) 576-6832 and K. C. Liu, (423) 574-5116

The objective of this task is to develop and demonstrate the capability of performing uniaxial tension-tension dynamic fatigue testing of structural ceramics at elevated temperature. The effort includes (1) design, fabrication, and demonstration of a load-train column capable of concentric load transfer between grip and specimen at high temperature; and (2) development of the baseline information on the tensile fatigue behavior of structural ceramics at room and elevated temperatures.

Keywords: Cyclic Fatigue, High Temperature Properties, Toughened Ceramics, Tensile Testing, Silicon Nitride

64. **TENSILE STRESS RUPTURE DEVELOPMENT (WBS NO. 3215)**
$300,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contacts: D. R. Johnson, (423) 576-6832 and K. C. Liu, (423) 574-5116

The objective of this task is to develop the test capability for performing uniaxial tensile stress-rupture and creep tests on candidate structural ceramics at high temperature in the range where time-dependent deformation can occur. Creep and creep-rupture design databases will be generated using uniaxial tensile specimens tested in the range of 1150-1370°C. The resulting stress-rupture and creep data will be used to evaluate and refine existing constitutive models. New constitutive models will be developed to facilitate design analyses of high-temperature structural components and improve their reliability.

Keywords: Creep, Silicon Nitride, High Temperature Properties, Tensile Testing, Time-Dependent

65. **LIFE PREDICTION VERIFICATION (WBS NO. 3216)**
$200,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contacts: D. R. Johnson, (423) 576-6832 and M. K. Ferber, (423) 576-0818

The goal of the proposed research program is to systematically verify life prediction methodologies appropriate for structural ceramic engine components. An emphasis will be to achieve predictability at a level acceptable to end users, in particular, those users associated with the manufacturing of internal combustion engine valves. This effort

is comprised of four tasks: (1) characterization of material/mechanical performance using standard testing coupons, (2) life prediction analysis of prototype diesel engine valves, (3) actual mechanical testing of prototype engine valves, and (4) verification of life prediction codes. A valve-testing facility will be specifically developed for static and cyclic tensile testing of the prototype valve geometries at appropriate temperatures.

Keywords: Engines, Failure Analysis, Failure Testing, High Temperature Service, Life Prediction, Mechanical Properties, Structural Ceramics, Tensile Testing, SiAlON, Silicon Nitride

66. **TOUGHENED CERAMICS LIFE PREDICTION (WBS NO. 3217)**
$200,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: D. R. Johnson, (423) 576-6832
NASA - Lewis Research Center Contact: John P. Gyekenyesi, (216) 433-3210

The purpose of this research is to understand the room-temperature and high-temperature behavior of toughened ceramics as the basis for developing a life prediction methodology. A major objective is to understand the relationship between microstructure and the mechanical behavior within the bounds of a limited number of materials. A second major objective is to determine behavior as a function of time and temperature. Specifically, strength and reliability, fracture toughness, slow crack growth, and creep behavior will be determined as a function of temperature for the as-manufactured material. The same properties will also be evaluated after long-time exposure to various high- temperature isothermal and cyclic environments. These results will provide input for parallel materials development and design methodology programs. Resultant design codes will be verified.

Keywords: Creep, Fracture Toughness, High Temperature Properties, Life Prediction, Silicon Nitride, Time-Dependent

67. **LIFE PREDICTION METHODOLOGY (WBS NO. 3222)**
$0
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: C. R. Brinkman, (423) 574-5106
Allison Contact: N. J. Provenzano, (313) 230-3150

The goal of this effort was to develop a methodology which can be used during the design phase to predict the structural behavior of ceramic components. There were four major technical tasks: (1) material database/material characterization, (2) development of nondestructive evaluation technology, (3) development of analytical life-prediction models, and (4) verification. GTE's PY6 injection-molded and hot isotropic pressed silicon nitride was selected for characterization which involved both room- and elevated-temperature tests using a variety of specimen types. Four failure modes were addressed: fast fracture, slow crack growth, creep, and oxidation. The life-prediction models developed as part of this work have been incorporated into NASA's CARES code.

Keywords: Creep, Failure Analysis, Failure Testing, Oxidation, Life Prediction, Nondestructive Evaluation, Silicon Nitride

68. **LIFE PREDICTION METHODOLOGY (WBS NO. 3223)**
$600,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: C. R. Brinkman, (423) 574-5106
AlliedSignal Engines Contact: N. Menon, (602) 231-1230

This Phase II program will develop the methodology required to adequately predict the useful life of ceramic components used in advanced heat engines. Phase II efforts will concentrate on predictive methodology for time- and cycle-dependent failure modes, as well as proof testing and nondestructive evaluation (NDE) methodology to enhance component reliability through screening out of low-strength components. The life prediction methodologies developed will be generic and hence will be applicable to ceramic components that operate under known temperature and stress conditions. The technical effort has been organized into six areas: (1) material baseline, (2) compressive creep methodology, (3) flaw growth methodology, (4) cyclic fatigue methodology, (5) proof test methodology, and (6) NDE reliability methodology.

Keywords: Creep, Failure Analysis, Failure Testing, Life Prediction, Nondestructive Evaluation, Silicon Nitride

69. **ENVIRONMENTAL EFFECTS IN TOUGHENED CERAMICS (WBS NO. 3314)**
$383,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: M. K. Ferber, (423) 576-0818
University of Dayton Contact: N. L. Hecht, (513) 229-4341

The objective of this task is to investigate the effects of environment on the mechanical behavior of commercially

available ceramics being considered for heat engine applications.

Keywords: Fatigue, Engines, Structural Ceramics, Environmental Effects, Alumina, Zirconia, Diesel Combustion, Tensile Testing, Time-Dependent, Transformation-Toughened

70. **HIGH TEMPERATURE TENSILE TESTING (WBS NO. 3412)**
$500,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: D. R. Johnson, (423) 576-6832
North Carolina A&T State University Contact: J. Sankar, (919) 334-7620

The objective of this research is to test and evaluate the long-term mechanical reliability of Si_3N_4 at temperatures up to 1300°C. Microstructural/microchemical analysis of the fracture surfaces using scanning electron microscopy (SEM), transmission electron microscopy (TEM), and energy-dispersive spectral analysis (EDS) is an integral part of this effort.

Keywords: Creep, Fracture, Silicon Nitride, Structural Ceramics, Tensile Testing

71. **STANDARD TENSILE TEST DEVELOPMENT (WBS NO. 3413)**
$125,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: D. R. Johnson, (423) 576-6832
NIST Contact: S. M. Wiederhorn, (301) 975-5772

This project was concerned with the development of test equipment and procedures for measuring the strength and creep resistance of ceramic materials at elevated temperatures to assist in the development of a reliable data base for use in the structural design of heat engines for vehicular applications. Inexpensive methods of measuring tensile creep of ceramics at elevated temperatures were developed.

Keywords: Creep, High Temperature Properties, Structural Ceramics, Tensile Testing, Test Procedures

72. **NON-DESTRUCTIVE EVALUATION (WBS NO. 3511)**
$335,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contacts: D. R. Johnson, (423) 576-6832 and D. J. McGuire, (423) 574-4835

The purpose of this program is to conduct nondestructive evaluation (NDE) development directed at identifying approaches for quantitative determination of conditions (including both properties and flaws) in ceramics that affect the structural performance. Those materials that have been seriously considered for application in advanced heat engines are all brittle materials whose fracture is affected by structural features whose dimensions are on the order of the dimensions of their microstructure. This work seeks to characterize those features using high frequency ultrasonics and radiography to detect, size, and locate critical flaws and to measure nondestructively the elastic properties of the host material. The studies will also address the problems unique to various fabrication techniques such as sintering, hot isostatic pressing, and gelcasting.

Keywords: Nondestructive Evaluation, Radiography, Structural Ceramics, Ultrasonics

73. **COMPUTED TOMOGRAPHY (WBS NO. 3515)**
$120,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: D. R. Johnson, (423) 576-6832
Argonne National Lab Contact: W. A. Ellingson, (312) 972-5068

The original objectives of the Phase III work of this project were to: (1) investigate the utilization of high-spatial resolution 3-D X-Ray microcomputed tomography techniques to study density distributions in composite green-state (as-cast) pressure slip cast ATTAP rotors, and (2) correlate destructive density analysis (to be conducted by AlliedSignal Ceramic Components) of the as-cast ATTAP rotors with the 3-D microtomography density data. Because the large ATTAP rotors are no longer of technical interest, a change is being made to refocus the work to the AS-800 Si_3N_4 Series 85 nozzles being produced by AlliedSignal Ceramic Components.

Keywords: Components, Computed Tomography, Nondestructive Evaluation, Silicon Nitride, Structural Ceramics, Green State

74. **NUCLEAR MAGNETIC RESONANCE (NMR) IMAGING (WBS NO. 3516)**
$80,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: D. R. Johnson, (423) 576-6832
Argonne National Lab Contact: W. A. Ellingson, (312) 972-5068

The purpose of this work is to evaluate the potential of NMR imaging to impact the development and process control of near-net-shape gelcast ceramic components. The specific objectives of this work are to determine the utility of NMR imaging for: (1) 3D mapping of polymerization homogeneity; (2) real-time imaging of the

polymerization process; (3) nondestructive evaluation of voids and flaws in the resultant components; and (4) measurement of physical properties such as degree of polymerization, viscosity, and specimen strength via correlation of these properties with measurable NMR parameters. This work is being performed in conjunction with Metals and Ceramics Division staff at Oak Ridge National Laboratory.

Keywords: Binder, Nondestructive Evaluation, Nuclear Magnetic Resonance, Silicon Nitride

TECHNOLOGY TRANSFER AND MANAGEMENT COORDINATION

75. **MANAGEMENT AND COORDINATION (WBS NO. 111)**
$700,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: D. R. Johnson, (423) 576-6832

The objective of this effort is to assess the ceramic technology needs for advanced automotive heat engines, formulate technical plans to meet these needs, and prioritize and implement a long-range research and development program.

Keywords: Advanced Heat Engines, Structural Ceramics, Management, Coordination, AGT, Diesel

76. **INTERNATIONAL EXCHANGE AGREEMENT (IEA) (WBS NO. 4115)**
$0
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contacts: D. R. Johnson, (423) 576-6832 and M. K. Ferber, (423) 576-0818

The purpose of this effort is to organize, assist, and facilitate international research cooperation on the characterization of advanced structural ceramic materials. A major objective of this research is the evolution of voluntary measurement standards for determining mechanical, physical, and structural properties for these materials. Participants in Annex II are the United States, Germany, Sweden, Japan, and Belgium. Current research is focused on Subtask 7, Ceramic Machining, and Subtask 8, Ceramic Powder Characterization.

Keywords: International Energy Agency, Powder Characterization, Mechanical Properties

77. **STANDARD REFERENCE MATERIALS (WBS NO. 4116)**
$150,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: D. R. Johnson, (423) 576-6832
NIST Contact: S. Malghan, (301) 975-5772

This project is directed toward a critical assessment and modeling of ceramic powder characterization methodology and toward the establishment of an international basis for standard materials and methods for the evaluation of powders prior to processing. The objectives of this program are: (1) to assist with the division and distribution of ceramic starting powders for an international round robin on powder characterization; (2) to provide reliable data on physical (dimensional), chemical, and phase characteristics of powders; and (3) to conduct statistical assessment, analysis, and modeling of round-robin data. The round-robin is to be conducted through the auspices of the International Energy Agency.

Keywords: International Energy Agency, Reference Material, Powder Characterization

78. **MECHANICAL PROPERTY STANDARDIZATION (WBS NO. 4121)**
$100,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: D. R. Johnson, (423) 576-6832
NIST Contact: G. Quinn, (301) 975-5765

The purpose of this effort is to develop mechanical test standards in support of the Ceramic Technology Project and the Advanced Turbine Technology Applications Program.

Keywords: Mechanical Properties, Test Procedures

DEVICE OR COMPONENT FABRICATION, BEHAVIOR OR TESTING

79. **ADVANCED COATING TECHNOLOGY (WBS NO. 1311)**
$175,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contacts: D. R. Johnson, (423) 576-6832 and D. P. Stinton, (423) 574-4556

Sodium corrosion of SiC and Si_3N_4 components in gas turbine engines is a potentially serious problem. The objective of this effort is to develop a coating that will protect the underlying SiC or Si_3N_4 from sodium corrosion and provide simultaneous oxidation protection. To

evaluate the behavior of potential materials such as stabilized ZrO_2 or HfO_2, TiO_2, and Ta_2O_5 in sodium-containing atmospheres, the corrosion resistance of hot-pressed samples of these materials will first be evaluated. A chemical vapor deposition (CVD) process will be developed for the application of the most promising coatings. The effect of the combustion environment upon coating characteristics such as microstructure, strength, adherence, and other properties will also be evaluated.

Keywords: Coatings, Chemical Vapor Deposition, Engines, Silicon Carbide, Silicon Nitride, Structural Ceramics, Corrosion Resistance, Mullite

80. **COATINGS TO REDUCE CONTACT STRESS DAMAGE OF CERAMICS (WBS NO. 1313)**
$0
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: D. R. Johnson, (423) 576-6832
Boston University Contact: V. K. Sarin, (617) 353-2842

The objective of this effort was to develop oxidation/corrosion-resistant, high toughness, adherent coating configurations for silicon-based ceramic substrates for use in advanced gas turbine engines.

Keywords: Adherence, Coatings, Contact Stress, Oxidation, Modeling, Corrosion Resistance, Mullite, Structural Ceramics

81. **WEAR RESISTANT COATINGS (WBS NO. 1331)**
$0
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: D. P. Stinton, (423) 574-4556
Caterpillar Contact: M. H. Haselkorn, (309) 578-6624

The goal of this effort is to develop wear-resistant coatings for application to metallic components of low-heat-loss diesel engines, specifically, piston rings and cylinder liners. The following wear-resistant coatings were selected in Phase I: plasma-sprayed high carbon iron-molybdenum, plasma-sprayed chromia-silica, and low temperature arc vapor deposited (LTAVD) chrome nitride. A plasma-sprayed carbon iron-molybdenum and a plasma-sprayed chromia-silica were identified as wear-resistant piston-ring coatings. The three main technical tasks for Phase II are further optimization of the LTAVD chrome nitride and cast iron porcelain enamel wear coatings, process scale-up of wear-resistant plasma coatings for cylinder-liner applications, and simulated engine testing.

Keywords: Coatings, Engines, Friction, Structural Ceramics, Wear

82. **WEAR RESISTANT COATINGS (WBS NO. 1332)**
$0
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: D. P. Stinton, (423) 574-4556
Cummins Contact: Malcolm Naylor, (812) 377-7713

The objective of this program is to develop advanced wear-resistant ceramic coatings for in-cylinder components for future, high-efficiency, low-emissions diesel engines. Coatings and substrates (for piston rings and cylinder liners) are to be developed to meet the following requirements:

- low wear as measured in laboratory rig tests which simulate the piston ring-cylinder liner environment near the top ring reversal in a heavy duty diesel engine
- lower friction coefficients than for the conventional system under all test conditions
- high adherence and compatibility with substrate materials
- good thermal shock resistance
- high uniformity and reproducibility

Keywords: Adherence, Coatings, Engines, Friction, Metals, Structural Ceramics, Thermal Conductivity, Wear

83. **THICK THERMAL BARRIER COATING SYSTEMS FOR LOW HEAT REJECTION DIESEL ENGINES (WBS NO. 1342)**
$0
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: D. P. Stinton, (423) 574-4556
Caterpillar Contact: M. Brad Beardsley, (309) 578-8514

The objective of this effort is to advance the fundamental understanding of thick thermal barrier coating (TTBC) systems for application to low-heat-rejection diesel engine combustion chambers. Areas of TTBC technology that will be examined include powder characteristics and chemistry; bond coat compositions; coating design, microstructure, and thickness as they affect properties, durability, and reliability; and TTBC "aging" effects (microstructural and property changes) under diesel engine operating conditions.

Keywords: Coatings, Structural Ceramics

84. **ACTIVE METAL BRAZING PSZ-IRON (WBS NO. 1411)**
$220,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contacts: D. R. Johnson, (423) 576-6832 and M. L. Santella, (423) 574-4805

The objective of this task is to develop strong, reliable joints containing ceramic components for applications in advanced heat engines. The overall emphasis is on studying the brazing characteristics of advanced ceramics such as silicon nitride, silicon carbide, and partially stabilized zirconia. The techniques of direct brazing with metallic and nonmetallic filler materials are being used. Vapor coatings are being used where appropriate to circumvent wetting problems associated with braze filler metals. The planned activities during FY 1995 will emphasize the use of structural analysis software to design joints for engine components such as valves and shaft attachments. The objective of this effort will be to identify material combinations and processing that would be feasible for these components, and to produce prototype parts whenever possible.

Keywords: Metals, Structural Ceramics, Joining/Welding, Brazing, Silicon Carbide, Silicon Nitride

85. **SURFACE DURABILITY OF MACHINED CERAMICS (WBS NO. 1500)**
$200,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contacts: D. R. Johnson, (423) 576-6832 and P. J. Blau, (423) 574-5377

The purpose of this task is to develop, in conjunction with U.S. industry, advanced technologies and the associated scientific and economic concepts necessary to reduce costs associated with the machining of structural ceramics, especially as related to component parts for energy-efficient, low-emissions transportation systems. This effort is conducted by industry, other national laboratories, and in-house at ORNL. The ORNL research concerns two technical areas: (1) investigating the effects of machining practices on the durability of ceramics for valve and valve-seat applications, (2) understanding and characterizing the detailed nature of machining-induced surface and subsurface damage and their evolution in advanced ceramic materials using a range of analytical tools.

Keywords: Cost-Effective Ceramics, Machining, Silicon Nitride, Structural Ceramics

86. **NEXT-GENERATION GRINDING WHEEL (WBS NO. 1501)**
$392,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: P. J. Blau, (423) 574-5377
Norton Contact: Robert H. Licht, (508) 351-7815

This effort is aimed at the engineering design and development of a next-generation, superabrasive grinding wheel specifically tailored for the cylindrical grinding of silicon nitride and other advanced structural ceramic parts for automotive and truck engine applications. The intent of this effort is to significantly reduce manufacturing cost of ceramic parts and to enhance the competitiveness of U.S. industry by providing an optimized grinding wheel for ceramics. The Phase I objectives to define requirements, and design, develop, and evaluate a next-generation grinding wheel for cost-effective cylindrical grinding of advanced ceramics have been met. A Phase II effort to scale up the new, superabrasive wheel developed in Phase I to larger diameters and conduct additional in-house wheel enhancement is planned.

Keywords: Cost-Effective Ceramics, Machining, Silicon Nitride, Structural Ceramics, Surface Characterization and Treatment

87. **GRINDABILITY TEST (WBS NO. 1502)**
$0
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: P. J. Blau, (423) 574-5377
Chand Kare Contact: Ronald H. Chand, (508) 793-9814

The objective of this program was to develop a cost-effective method to determine the grindability of ceramics leading to cost-effective methods for machining those materials. Phase I efforts were directed towards a review of literature related to ceramic grinding, development of a variable definition of grindability, design of grindability test experiments, and design of a ceramics grindability test system. The grindability study also included establishment of correlation between the grindability number and conventional grinding practices. Fabrication of the final prototype of the ceramic grindability test system has been completed.

Keywords: Cost-Effective Ceramics, Machining, Silicon Nitride, Structural Ceramics, Surface Characterization and Treatment

88. **CHEMICALLY ASSISTED GRINDING OF CERAMICS (WBS NO. 1503)**
$150,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: P. J. Blau, (423) 574-5377
NIST Contact: Steven M. Hsu, (301) 975-6119

The objective of this effort is to reduce ceramic machining costs by increasing the machining rate of ceramics using chemical reactions at the interface. The approach is to use chemistry to control the machining process. The ceramic surface can be chemically modified to form a soft reaction layer which can be removed rapidly with minimum substrate penetration, thus reducing stresses and minimizing residual cracks. Si_3N_4 is the material of focus. The current focus is on the role of coolants in the machining of ceramics, including testing coolants under actual production conditions.

Keywords: Chemical Reaction, Cost-Effective Ceramics, Machining, Silicon Nitride, Structural Ceramics, Surface Characterization and Treatment

89. **GRINDING CONSORTIUM (WBS NO. 1503)**
$150,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: P. J. Blau, (423) 574-5377
NIST Contact: Said Jahanmir, (301) 975-6871

The purpose of this effort was to develop guidelines and recommendations for grinding optimization of advanced structural ceramics to achieve minimum cost and maximum reliability. The following steps were taken to achieve the objective: conduct grinding experiments jointly with industrial participants, determine the effect of grinding parameters on machining damage and strength, elucidate mechanisms of material removal and damage formation, evaluate several damage detection techniques, and transfer data and information to industry in computerized database format.

Keywords: Database, Cost Effective Ceramics, Machining, Silicon Nitride, Structural Ceramics, Surface Characterization and Treatment

90. **HIGH SPEED GRINDING (WBS NO. 1504)**
$372,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: P. J. Blau, (423) 574-5377
Eaton Contact: Joseph A. Kovach, (216) 523-6766

The purpose of this effort is to develop a single-step, rough finishing process suitable for producing high-quality silicon nitride ceramic parts at high material removal rates and at substantially lower cost than traditional, multi-stage grinding processes.

Keywords: Cost Effective Ceramics, Machining, Silicon Nitride, Structural Ceramics, Surface Characterization and Treatment

91. **LASER-BASED NDE METHODS (WBS NO. 1507)**
$180,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: D. R. Johnson, (423) 576-6832
Argonne National Lab Contact: J. G. Sun, (708) 252-5169

The primary objective of this effort is to develop a laser-scattering procedure which would provide a direct indication of changes in the subsurface (and surface) during machining-both machining-induced damage such as median crack formation and surface roughness. A second objective is to evaluate dye-penetrant technology as an off-line indicator for surface-breaking cracks.

Keywords: Machining, Nondestructive Evaluation, Structural Ceramics

92. **GRINDING MACHINE STIFFNESS (WBS NO. 1510)**
$227,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: P. J. Blau, (423) 574-5377
University of Connecticut Contact: Bi Zhang, (203) 486-3576

The objective of this new effort is to determine the minimum required grinding machine stiffness to meet acceptable quality requirements for ground silicon nitride ceramic parts.

Keywords: Machining, Silicon Nitride

93. **NEXT GENERATION GRINDING SPINDLE (WBS NO. 1511)**
$225,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: P. J. Blau, (423) 574-5377
Eaton Contact: J. A. Kovach, (216) 523-6766

The objective of this new effort is to design, develop, test, and demonstrate the operation of a next generation, high-stiffness, high-speed spindle to be used for centerless grinding of ceramic parts.

Keywords: Machining, Structural Ceramics

94. **PROCESS COST MODEL (WBS NO. 1512)**
$250,000
DOE Contact: Robert B. Schulz, (202) 586-8051
ORNL Contact: S. G. Winslow, (423) 574-0965
AlliedSignal Ceramic Components Contact:
B. S. Draskovich, (312) 512-5654

The objective of this new effort is to refine and utilize a process cost model for the evaluation of various fabrication methods used to manufacture diesel engine and aerospace/industrial turbomachinery structural ceramic components and provide a report containing an analysis of the process cost modeling effort.

Keywords: Cost-Effective Ceramics, Cost Reduction, Modeling, Processing, Structural Ceramics

OFFICE OF PROPULSION SYSTEMS

The Office of Propulsion Systems is comprised of the Advanced Propulsion Division and the Electric and Hybrid Propulsion Division. R&D programs focus on developing the technologies that will lead to the production and introduction of advanced heat engine propulsion systems, and electric and hybrid vehicles, in the Nation's transportation fleet. Technology development is conducted in concert with industry through cost-shared contracts. Materials activities of the Office of Propulsion Systems focus on integration of materials into components, and testing of subsystems for advanced vehicle propulsion systems.

ADVANCED PROPULSION DIVISION

The Advanced Propulsion Division consists of two programs: (1) Light Duty Engine Technologies Program, targeting Turbine Engine Technologies and Advanced Piston Engine Technologies; and (2) Heavy Duty Engine Technologies Program, targeting Advanced Diesel Engine Technology. Materials activities are supported by the Advanced Propulsion Division and managed through the NASA Lewis Research Center and the Oak Ridge National Laboratory. The DOE Contacts are: Thomas Sebestyen, (202) 586-8012 for Turbine Engine Technologies; Patrick Sutton, (202) 586-8058 for Automotive Piston Engine Technologies; and John Fairbanks, (202) 586-8066 for Heavy Duty Engine Technologies.

MATERIALS PROPERTIES, BEHAVIOR, CHARACTERIZATION OR TESTING

95. **NASA SUPPORTING RESEARCH AND TECHNOLOGY**
$100,000
DOE Contact: Thomas Sebestyen, (202) 586-8012
NASA Contact: Thomas Strom, (216) 433-3408

The objective of this program is to evaluate commercially available structural and glass ceramic material specimens exposed to combustion products at temperatures up to 2500°F for periods up to 3,500 hours. Activities include: development of design codes for structural component evaluation; research on non-destructive evaluation of ceramic components to improve reliability; and examination of the effects of corrosive sea salts and other adverse environments on the durability of ceramics.

Keywords: Structural Ceramics, Nondestructive Evaluation, Silicon Carbide, Silicon Nitride, Gas Turbine Engines

DEVICE OR COMPONENT FABRICATION, BEHAVIOR OR TESTING

96. **HYBRID VEHICLE TURBINE ENGINE (HVTE) TECHNOLOGY SUPPORT**
$3,600,000
DOE Contact: Thomas Sebestyen, (202) 586-8012
NASA Contact: Paul Kerwin, (216) 433-3409
Allison Engine Company Contact: Steve Berenyi, (317) 230-6971

The Hybrid Vehicle Turbine Engine (HVTE) Technology Support Program focuses on the DOE Hybrid Vehicle Program turbine engines in the 20-60kW size for hybrid vehicle application. In support of the advanced HVTE, Allison is designing, fabricating, and testing low-emission combustors, ceramic hot section components, a high performance ceramic regenerator core and seal system and cost-effective high temperature insulation system. Test rigs and test bed engines are being used to evaluate full-scale component and subsystem reliability and durability at cyclic operating conditions that are typical of automotive use at up to 2500°F.

Keywords: Structural Ceramics, Component Design, Silicon Carbide, Silicon Nitride, Gas Turbine Engines, Rig and Engine Testing